DEVELOPMENT OF ON-ORBIT FLUID GAGING TECHNIQUES

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V112AA4-1

TWO FLUID QUANTITY GAGING PROGRAMS IN PROGRESS

- OBJECTIVE: MEASURE LIQUID MASS TO ±1% IN TWO-PHASE TANKS ON ORBIT

- FIRST: AIMED AT LIQUID O_2, H_2 FOR PROPULSION
  - SELECTED RF MODAL MEASUREMENT METHOD
  - BEGUN BY BEECH AIRCRAFT, NOW AT BASD

- SECOND: AIMED AT OTHER CRYOGENIC AND EARTH STORABLE FLUIDS
  - SELECTED COMPRESSION METHOD

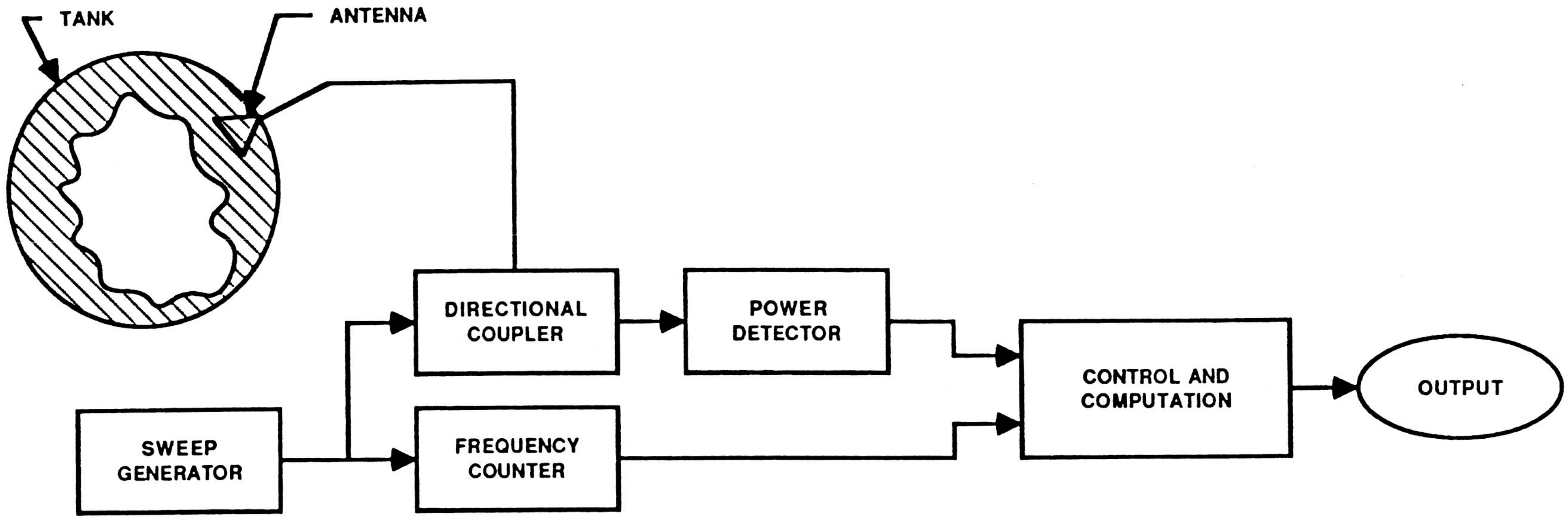
V112AA4-2

R.F. MODAL GAGING PROGRAM

DESCRIPTION:	SELECT CONCEPT FOR MEASURING LIQUID O_2 AND H_2 IN RANGE OF TANK SIZES ON ORBIT. BUILD DEVELOPMENT UNIT AND SUPPORT GROUND AND KC-135 TESTING AT NASA-JSC.
FLUIDS OF INTEREST:	H_2, O_2
CUSTOMER:	NASA-JOHNSON SPACEFLIGHT CENTER (NANCY MUNOZ)
CONTRACT VALUE:	$0.8M
PERIOD OF PERFORMANCE:	MAY 1985 TO FEBRUARY 1989

V112AA4-3

R.F. MODAL GAGING CONCEPT



- STANDING WAVE (MODE) FREQUENCIES RELATED TO QUANTITY OF DIELECTRIC (FLUID) IN TANK
- MEASURE FREQUENCIES OF 2 SELECTED MODES TO COMPENSATE FOR EFFECT OF BUBBLE LOCATION/CONFIGURATION

V112AA4-4

PROGRAM STATUS & ANTICIPATED RESULTS

- FEASIBILITY TESTING IN 530-LITER TEST UNIT GAVE $\leq 1.3\%$ ACCURACY
  - TILTED TANK IN 1-G FIELD
  - TESTED WITH LIQUID N_2, O_2, H_2

- SUB-SCALE TESTING TO ASSESS EFFECT OF DIFFERENT BUBBLE CONFIGURATIONS UNDER WAY
  - SIMULATING CRYOGEN WITH PARAFFIN

- DEVELOPMENT UNIT FABRICATION SCHEDULED FOR AUGUST 1987

- EXPECTED PROGRAM END PRODUCTS:
  - TEST RESULTS SHOWING 1% ACCURACY
  - DEVELOPMENT UNIT FOR USE AT JSC IN LAB AND ON KC-135
  - CONCEPT READY TO BEGIN DESIGN OF FLIGHT ARTICLE

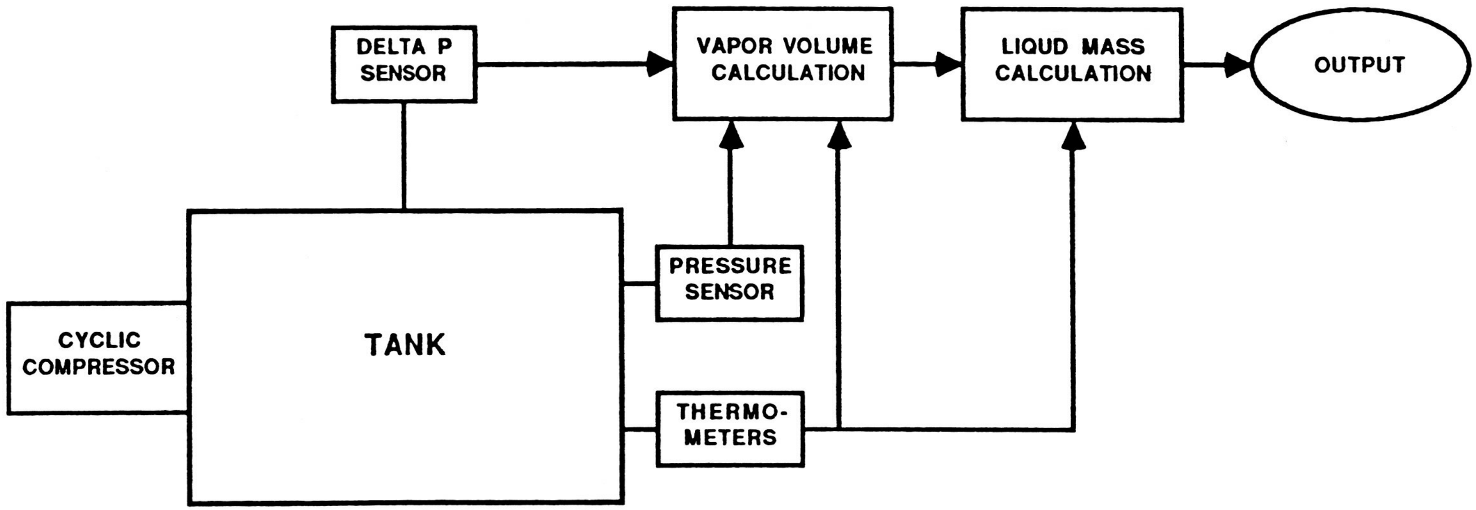
V112AA4-5

COMPRESSION GAGING PROGRAM

DESCRIPTION:	SELECT CONCEPT FOR MEASURING LIQUID QUANTITY ±1% IN TWO-PHASE STORAGE TANKS ON SPACE STATION. BUILD AND TEST BREADBOARD ON GROUND.
FLUIDS OF INTEREST:	MMH, NO_4, N_2, Ar, H_2O, HYDRAZINE
CUSTOMER:	NASA-JOHNSON SPACEFLIGHT CENTER (KEN KROLL)
CONTRACT VALUE:	$1.3M
PERIOD OF PERFORMANCE:	APRIL 1986 TO APRIL 1988

V112AA4-6

COMPRESSION GAGING CONCEPT



- ADIABATIC COMPRESSION OF VAPOR VOLUME (ABOUT 0.01% OF TANK VOLUME)
- PRESSURE RISE GIVES VAPOR VOLUME

$$V_{vapor} = -\gamma \Delta V (P/\Delta P), \text{ WHERE } \gamma = C_p/C_v$$

V112AA4-7

PROJECT STATUS & ANTICIPATED RESULTS

- SMALL-SCALE TESTS SHOWING AGREEMENT WITH THEORY TO LESS THAN 1%

- 210 LITER ROOM-TEMPERATURE ARTICLE (USING WATER) NEAR COMPLETION

- CRYOGENIC (LIQUID NITROGEN) TESTS SCHEDULED FOR FALL 1987

- EXPECTED PROGRAM END PRODUCTS:
  - TEST RESULTS SHOWING 1% ACCURACY
  - BREADBOARD TEST ARTICLE AT JSC USABLE IN LAB OR ON KC-135
  - CONCEPT READY TO BEGIN FLIGHT ARTICLE DESIGN

V112AA4-8

SPEAKER: ALLAN J. MORD/BALL AEROSPACE SYSTEMS DIVISION

John R. Schuster/General Dynamics Space Systems:

How much energy does it take to run the RF system? That is, how much might get deposited in the fluid in the tank? That's one question. The other question is, what is the frequency of the cyclic compression system and how many cycles do you need to let it run before you feel you have an accurate measurement?

Mord:

I don't know the answer to the first question. On the scale of interest, we are talking about putting watts into a tank, so I presume that it's negligible. On the compression method, we'll probably be running about 1 Hertz, and something on the order of about 100 cycles is what we need to get a good measurement.

John M. Cramer/Marshall Space Flight Center:

What test fluid are you going to be able to use on the KC-135 for the RF gauge?

Mord:

I can't speak to that. I am not working that program directly.

Franklin T. Dodge/Southwest Research Institute:

In the piston method, I guess you depend upon being able to communicate your pressure to all the vapor in the tank. Is there some way that the vapor might be hiding, say behind screens and things, and you wouldn't be able to communicate the pressure?

Mord:

It depends on how fast you do it. That effect goes as frequency-squared and that is something we are looking at analytically. We believe we are operating at a low enough frequency that the pressure nonuniformities are very small. That could be a very serious problem especially if we try to operate at frequencies higher than 1 Hertz.

Edwin C. Cady/McDonnell Douglas Astronautics:

Will the compression method work with the compressor under water, or do you have to have it in the vapor?

Mord:

One of our design requirements is that we can't depend on keeping either the compressor or the gauge unit dry. It may be advantageous to us to keep the gauge units wet all the time, but, no, we cannot allow ourselves that restriction.

Don T. Perkinson/Marshall Space Flight Center:

How rapidly can you update the information from the RF unit?

Mord:

That I don't know. I would expect it to be potentially much faster than on the compression unit, because you are operating at a very high frequency and you can make your detector very sensitive. I would expect you could get signal to noise discrimination very rapidly. I suspect that you would be limited only by the processing time for the algorithms to take the data and apply this two-frequency correction. It could be updated in seconds, less than a second, I don't know; how fast do you need it? I think you can get it as fast as you need it.

John P. Gille/Martin Marietta Denver Aerospace:

What was the fluid you used on the compression method where you got 1 percent accuracy?

Mord:

We used water.

Gille:

Have you tried this technique with something with a high vapor pressure?

Mord:

For purposes of the compression method, the world separates into two classes: a liquid pressurized with something other than itself and things in equilibrium with their own vapor where you are concerned about evaporation and condensation. We are going to do nitrogen testing next.

Gille:

My question then is, don't you feel that there would be a significant effect of what the interfacial area was for that case?

Mord:

No, we've already done quite a bit of analysis of the thermodynamics and our initial concern was that evaporation and condensation would just kill it. The answer is no if we do it fast enough, and fast enough turns out to be 1 Hertz.

Chip Meserole/Boeing Aerospace:

With the RF gauge, you mentioned the sensitivity to the tank configuration. Do you have to use a RF mode that equally distributes energy throughout the tank to get that accuracy?

Mord:

We'd like to, but I don't think there is one mode that distributes the energy equally throughout the tank. That whole question of how you get an adequately uniform sampling of the whole contents of the tank with these RF modes that have very complicated shapes and an electric field which goes to zero at all the metallic boundaries; that is a real theoretical quagmire.

Walter Swift/Creare, Inc.:

Did you run the life tests on the bellows at cryogenic temperatures?

Mord:

No, the one that we have is made from a steel that we would not expect to handle cryogenic temperatures. We are going to be building a second unit that is the right kind of steel with the right kind of design.